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MARS SAMPLE SURVIVABILITY TESTING FOR MARS SAMPLE RETURN

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12th International Planetary Probe Workshop
Cologne, Germany
June 15-19, 2015

Introduction

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- M2020 rover will be coring and caching Mars samples for potential future Earth return
- In returning to Earth, samples would be exposed to a range of different and stressing environments
- To maximize science return, samples must maintain mechanical integrity through Earth return
- Currently, there is little understanding as to how Mars rocks would behave when subjected to these future environments
- Understanding the mechanical behavior of these rocks could influence design of the Mars 2020 sample caching system and future Mars Sample Return (MSR) missions

Potential Mars Sample Return Campaign

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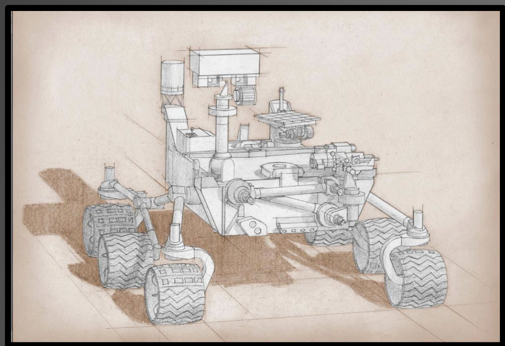
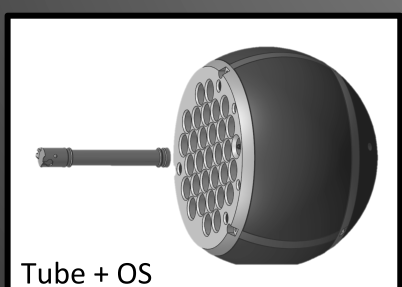
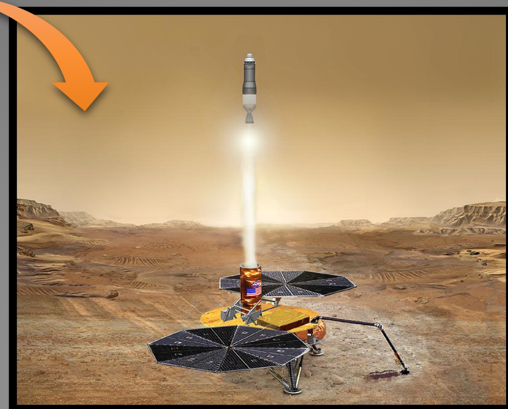


Sample Caching Mission

- Select, drill, encapsulate, and cache Mars rock cores

Stressing Loads
- Rotary percussive coring





Sample Retrieval Mission

- Retrieve samples from Mars surface
- Launch samples into Mars orbit

Stressing Loads
- Quasi static loads
- Random vibration
- Acoustic noise
- Pyroshock

Sample Return Mission

- Acquire samples in Mars orbit and return samples to Earth
- Fully passive EEV

Stressing Loads
- Earth impact
- Quasi-static loads
- Dynamic environment

Future Stressing Environments

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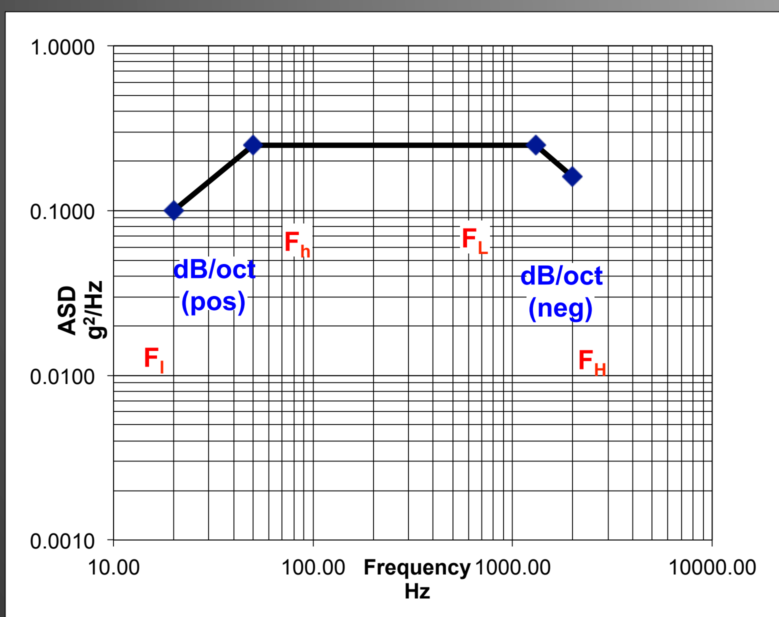
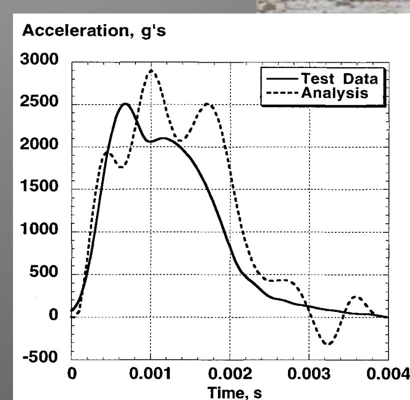
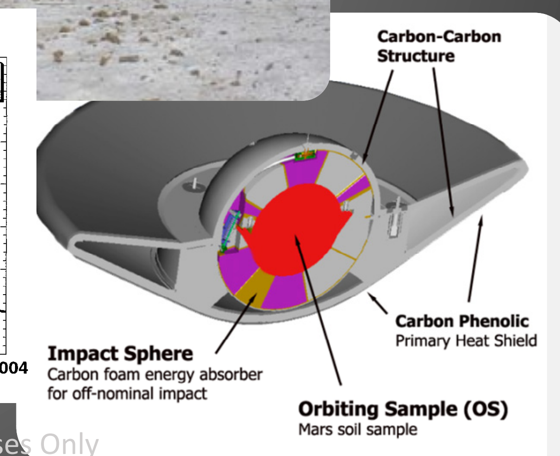
- Random vibration environment for Mars Ascent Vehicle (MAV):

FREQ(Hz)	ASD(g^2/Hz)	dB/OCT	Grms
20.00	0.1000	*	*
50.00	0.2500	3.01	2.29
1300.00	0.2500	0.00	17.83
2000.00	0.1600	-3.12	21.37



- Passive Earth Entry Vehicle (EEV) design for planetary protection Results in "hard" impact at Earth
  - Soft soil impact of 2500 g's (science target)
  - Hard surface impact of 3500 g's (containment target)





Test Setup: Clamshells

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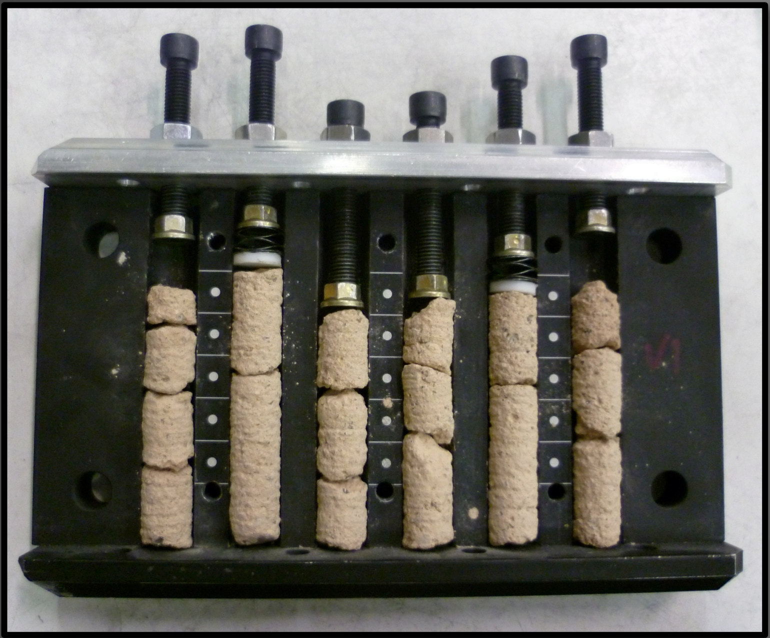
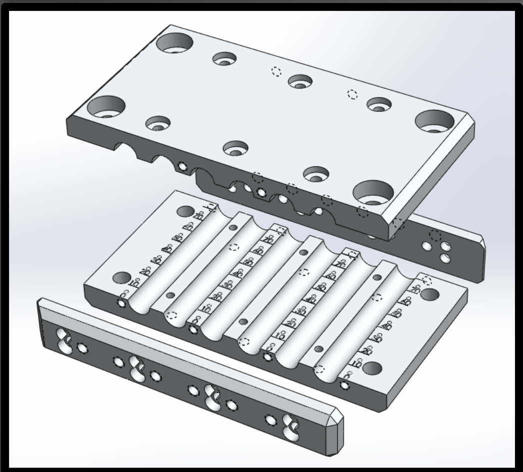
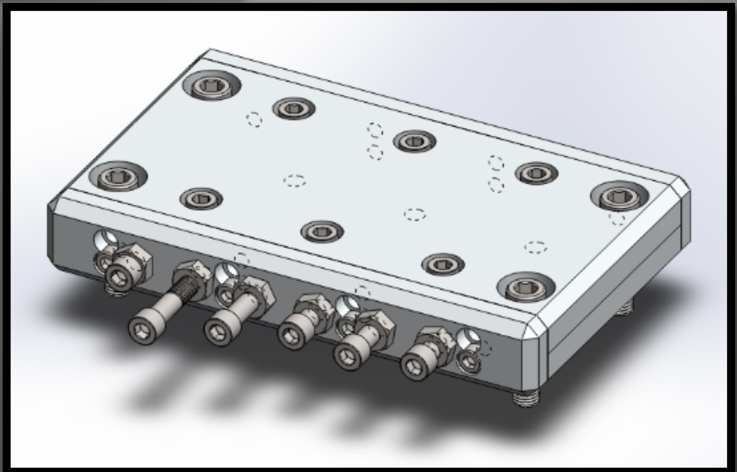


Clamshell Design

- Holds 6 rock cores each
- 2 versions accommodating 12mm and 13mm cores (with 0.5mm radial clearance)
- Accommodates varying core lengths
- Multiple approaches to retaining the samples
  - Variable headspace
  - No headspace
  - Secured via a spring (~20N preload)





Test Setup: Vibration Testing

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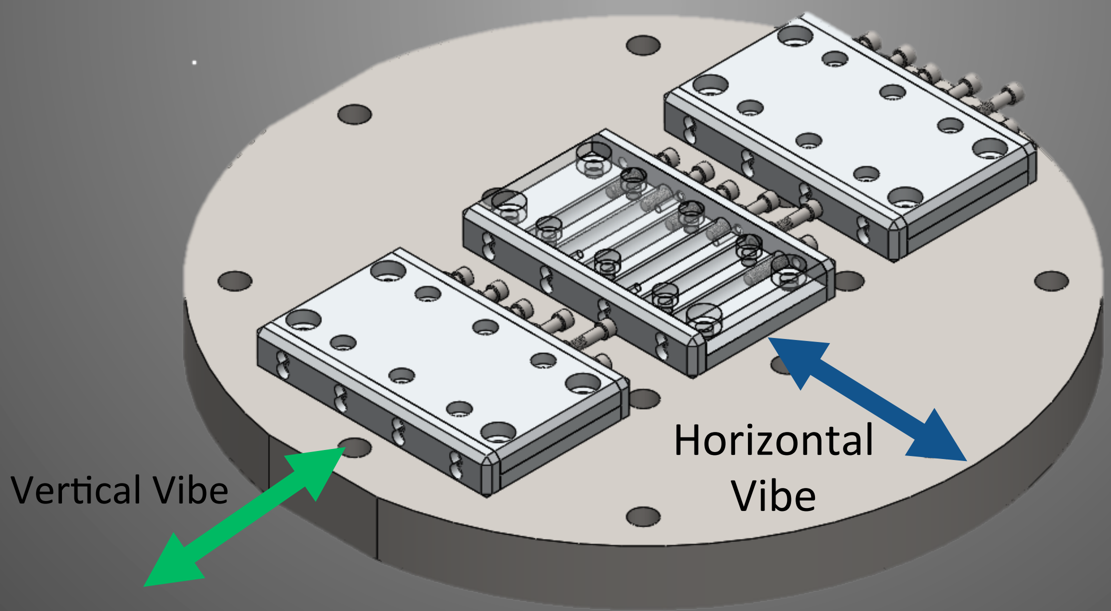
- Utilizing a small shake table in JPL's Environmental Test Laboratory
- 3 clamshells are mounted to a circular vibration mount
- Samples can be vibrated in horizontal, vertical, and skew (45°) axes
  - [Vertical = along length of core]
  - Assuming orientation of cores with respect to gravity is not important



Test Setup: Impact Testing

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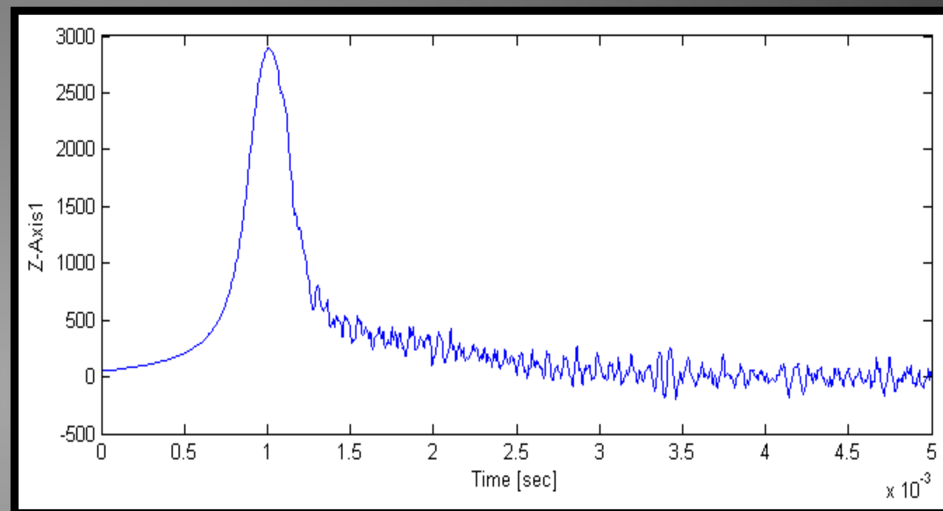
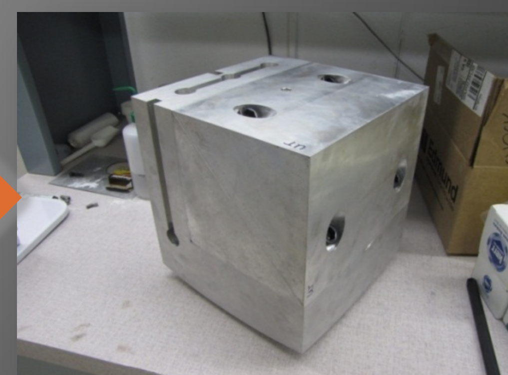
- 100 lb aluminum alloy drop block
- 7 meter drop height onto cork
- Achieves ~3000 g's max deceleration
- Accommodates 3 clamshells per drop:
  - Vertical (along length of core)
  - Horizontal
  - Skew (45°)




Vertical and Horizontal


Skew (45°)


The Completed Cube

Mars Analog Rock Selection

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Not Lithified (Regolith)	Very Weakly Lithified	Weakly Lithified	Medium Strength	Strong	Very Strong	Extremely Strong

Old Dutch Pumice

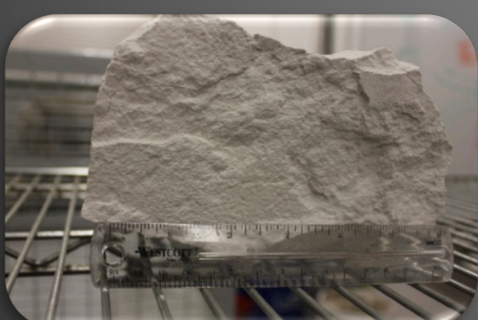
- Weak (~1-10 MPa compressive strength)
- Unaltered igneous (pyroclastic)
- Mechanically consistent

China Ranch Gypsum

- Medium (~10-80 MPa compressive strength)
- Hydrated sulfate
- Higher biosignature preservation

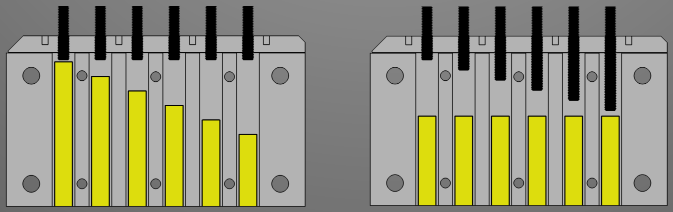
Bishop Tuff

- Medium strength
- Volcanic ash flow
- Similar mechanical properties
- Relatively water-insensitive



Initial Impact Testing: Chalk

- Initial impact testing using chalk
  - Readily available
  - Used to determine general sensitivities
  - 12 mm diameter cores
  - Up to 8cm in length
- Initial tests varied following parameters:
  - Orientation: horizontal, vertical, skew (45°)
  - Headspace: amount of vertical clearance in channel (0 to 50%)
    - Including consideration of cores “stuck” at top of channel



Initial Impact Testing: Chalk

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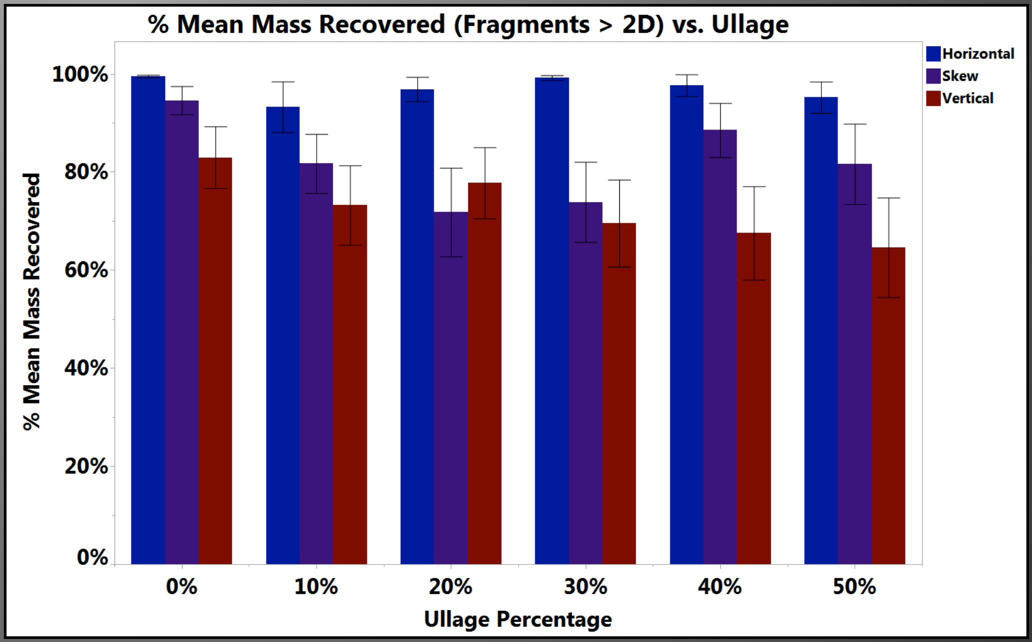
- Orientation:
  - Greatest damage to samples dropped in vertical orientation
  - Cores "stuck" to top of channel experienced significantly more damage in vertical orientation
- Headspace:
  - Increasing headspace increases damage to samples, mainly in vertical orientation

Test U16, Vertical Orientation, 3000 g's



Mars Analog Core Testing: Vibration

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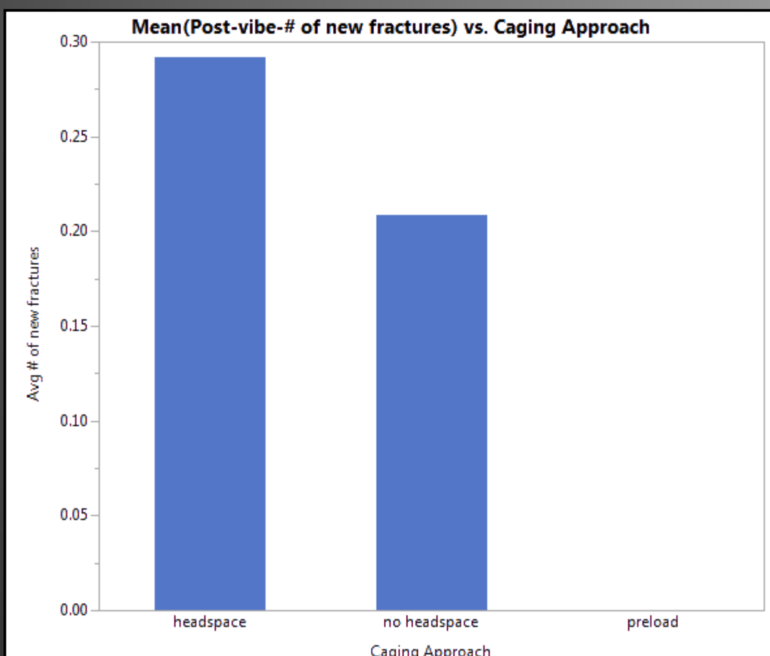
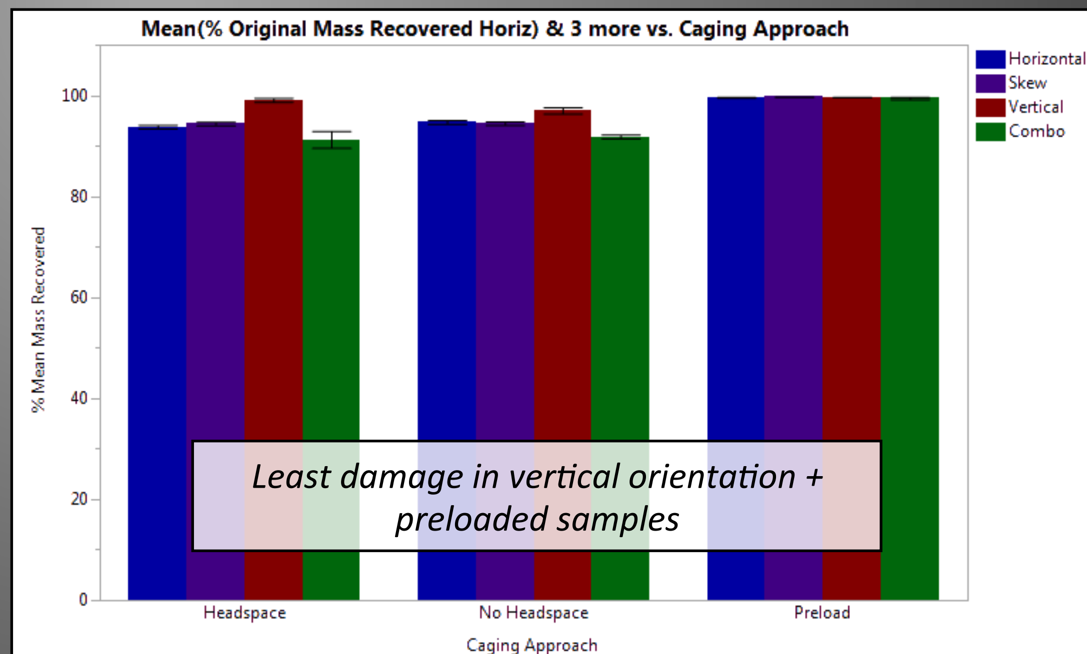
- Vibration tests conducted on Mars Analog rock: Bishop Tuff
  - 72 cores tested
  - 20-2000 Hz, 21.37 G_{rms}, 3 minute duration
  - 18 cores each individually in horizontal, vertical, and skew configurations
  - 18 cores exposed to horizontal + vertical (cumulative)
  - Sample retention: 12mm headspace, No headspace, 20N preload





Mars Analog Core Testing: Impact

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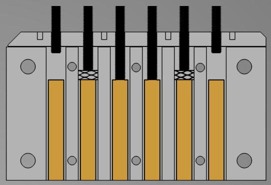
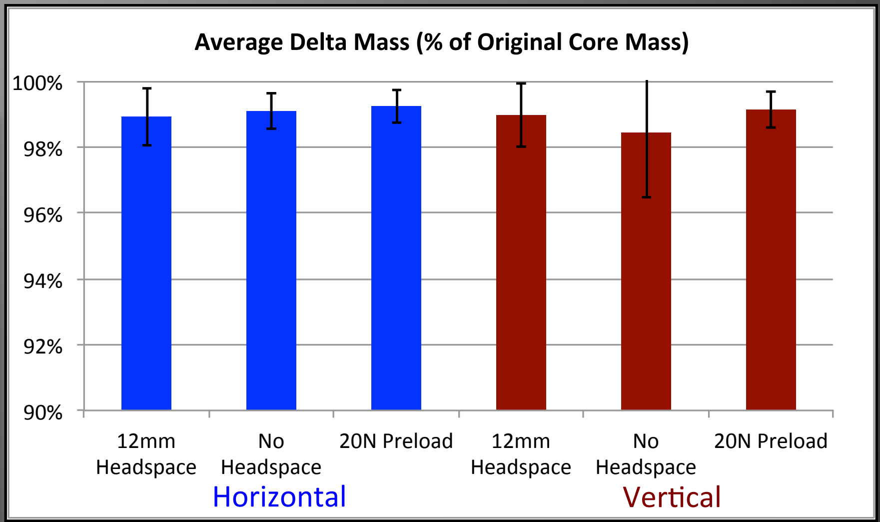
- Impact tests conducted on Mars Analog rocks: Bishop Tuff & Old Dutch Pumice
  - 36 cores tested for each rock type (3 total drops at 3000 g impact deceleration)
  - 18 cores each in horizontal and vertical configurations
  - 3 approaches tested for sample retention:
    - 12mm headspace
    - No headspace
    - No headspace + 20N preload



- Bishop Tuff: Little damage seen across all orientations & sample retention approaches
- Old Dutch Pumice: Results pending…

Drop #1, Vertical Orientation, 3000 g's, Before + After



Results & Future Work

- Initially investigated sensitivities using chalk
  - Impact in horizontal orientation is preferred
  - Minimal headspace is preferred
- Completed initial round of testing using Mars analog rocks
  - Bishop Tuff is fairly resilient to the expected MAV random vibration and peak impact deceleration
  - Caveat: while drop tower achieves maximum likely peak deceleration, the overall energy imparted is less (lower impact velocity)
- Additional vibration and impact testing planned for a range of weaker Mars analog rock materials
- Larger drop tower currently under fabrication which will allow for greater impact velocities and therefore better representation of expected impact pulse
- Transition to testing sample cores using hardware representative of M2020 and future missions (tubes, plugs/seals, OS, EEV)

References

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3. Dillman, R., and Corliss, J., 6th International Planetary Probe Workshop, Atlanta, GA, 21-27 June 2008.
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THANK YOU

Please contact the author if interested in obtaining a copy of the final report:

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